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Molecular exchange in liquid-vapour system in presence of inert gas

NARAYAN SWAROOP SINGHAL

Department of Physics, Indian Institute of Technology, New Delhi 110029

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In recent years, the liquid metals have been used in the nuclear power plants for heat transfer purposes. Since most of the liquid metals are highly reactive in the presence of oxygen and moisture, therefore, the inert gas is used in the heat transfer systems. But the heat transfer principles of the liquid metals in the presence of inert gas are not very well known. In a liquid-vapour system at thermodynamic equilibrium there is an exchange of the molecules in the liquid phase and vapour phase. This process is known as molecular exchange phenomenon (Singhal 1973*a*, 1973*b*, 1973*c*, 1973*d*). The rate of the molecular exchange process is given by Singhal (1973*a*)

$$J = \sigma n\bar{c}/4 \text{ mols./cm}^2 \text{ sec}, \qquad \ldots \quad (1)$$

where n = number density of the molecules in the vapour phase corresponding to the temperature T.

$\bar{c}$ = average thermal velocity of the molecules in the vapour phase corresponding to the temperature T.

σ = molecular exchange coefficient.

The value of σ is obtained experimentally and this may vary with the conditions under which the experiment is performed, and may be different for different materials. The result of the mass transfer analysis for the technique used in Singhal (1973*a*) to study the exchange process is

$$R_{cpm} = 1-\exp(-t/\tau) = \frac{(CPM/w)_v}{(CPM/w)_1} \qquad \ldots \quad (2)$$

where t = time period for the exchange process,

$\tau = \dfrac{VC_{vs}}{JA\sigma}$ = time constant for the exchange process,

V = volume of the vapour chamber,

C_{vs} = concentration of the normal molecules in the saturated vapour phase,

A = area of the radioactive liquid surface used for the exchange process,

$(CPM/w)_v$ = counts per minute per unit mass of the vapours at exchange time t,

$(CPM/w)_1$ = counts per minute per unit mass of the radioactive liquid at $t = 0$.

The experimental data can be collected for the exchange process in presence of inert gas, from these data a value of the exchange coefficient σ_i can be obtained.

An apparatus used for this investigation is given in Singhal (1972).

Mercury has been used as test material in the presence of argon gas for this investigation. The untagged and tagged mercury samples are loaded in the holders and then the holders are placed back in the system. The system is evacuated and heated. Then the flask is disconnected from the vacuum system by a three way stopcock. Argon gas is introduced into the flask to a desired pressure through another stopcock. The flask is filled with the saturated vapours of untagged mercury by opening the valve of a holder. Then, the mercury valve for radioactive mercury is opened for a predetermined time interval to allow the molecular exchange between vapor phase and liquid phase. The mercury vapors are condensed and then weighed. The radioactivity in the condensed sample is measured. From these data value of exchange coefficient is calculated. This procedure is repeated to obtain the data for various values of argon gas pressure.

Data :

Test material—mercury; inert gas—argon; temp. = 114°C; $V = 2.15 \times 10^3 \text{cm}^3$; $A = 0.402$ cm²; $VC_{vs} = 10.16 \times 10^{-3}$ gms; $J = 2.4 \times 10^{-2}$ gms/cm²-sec; pressure of saturated vapour P_{vs} = 573 microns; pressure of inert gas = P_i in microns; exchange coefficient with inert gas = σ_i.

Table 1

Run no.	P_i	P_i/P_{vs}	σ_i
1	0	0	0.059
2	50	0.087	0.016
3	100	0.175	0.010
4	200	0.349	0.009

References

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